

## HEAT-SHRINK JOINTING

The present invention relates to a heat-shrink jointing for an electrical power cable, in particular a medium voltage power cable operating at voltages typically between 12 kV and 5 42 kV inclusive.

Heat-shrink jointings for electrical power cables use heat-shrinkable polymeric technology to provide one or more heat recoverable sleeves having appropriate electrical characteristics which are shrunk into position around the ends of cables that have been 10 electrically connected together. There are two main types of heat-shrink electrical cable jointing currently in use for medium voltage (MV) electrical power cables.

A first type of jointing, as shown in Figs. 1a and 1b hereto, comprises a two-piece system that uses only heat-shrink materials to provide two heat recoverable sleeves that 15 respectively provide insulation and the external conductive layer required in the joint. An insulating-only sleeve 1 is installed first around the cable joint. A second, dual-layer sleeve 2 with a conductive outer layer 3 and an insulating inner layer 4 is then installed over the top of first sleeve 1 to provide a thicker insulating layer 4 and the required conductive outer layer 3.

This jointing is limited by the fact that it is not practical to manufacture sleeves 20 comprising a thick wall of thermoplastic, heat-shrink material owing both to manufacturing difficulty, and to the problem posed in heating through the entire wall thickness of a thick tube sufficient to recover it, without over-heating the outer surface to the extent that damage occurs. This means that the maximum wall thickness of the insulating material is limited 25 making it necessary to use multiple insulating sleeves 1 to create the required insulation thickness. Typically, two such sleeves are required for power cables operating at voltages up to around 24 kV. However, three or more insulating sleeves are required if a higher voltage rating is required for the joint. The use of multiple sleeves, however, causes its own problems not only because installation is prolonged but also because the increased number of interfaces 30 between the multiple sleeves 1 can lead to electrical problems as a result of air entrapment, contamination of the joint and the like.

The second type of jointing, as shown in Fig. 2, comprises a single-piece, elastomeric insulating jointing 5 in which a conducting heat-shrink outer layer 6 is used as a hold-out

mechanism for an elastomeric, insulating inner layer 7. The insulating inner layer 7 exerts an elastic force to shrink the jointing 5 but is prevented from doing so by the conductive, thermoplastic outer layer 6 that remains rigid until it is heated.

5        This second type of jointing obviates the problems created by the use of multiple sleeves by replacing the inner thermoplastic insulating sleeve by an elastic layer 7 that can recover without needing heat. This elastic layer 7 is retained in an expanded form by the outer rigid conductive layer 6 that prevents recovery of the jointing 5 until the outer layer 6 is heated during installation. However, there are two main problems with this system. First, the  
10      elastomeric inner layer 7 is slower to recover than the heat-shrink materials used in the first system. Second, because the elastic layer 7 is not rigid, the only mechanism which prevents its recovery prior to installation is the rigid, conductive outer layer 6. This means that the outer layer 6 is usually thicker than would otherwise be required for electrical reasons, thus adding materials and therefore cost to the product.

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      The object of the present invention is to provide a heat-shrink jointing for an electrical power cable that overcomes or substantially mitigates the aforementioned problems of conventional jointing systems.

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      According to the present invention there is provided a heat-shrinkable jointing for an electrical power cable comprising a sleeve or other hollow article having an electrically insulating inner layer, an electrically conductive outer layer, and between the inner and outer layers a thermoplastic mid-layer which can be softened by application of heat to the said sleeve or article to cause and/or permit dimensional recovery thereof.

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      Preferably, the insulating inner layer is comprised of an elastomeric material, which may contribute to the recovery of the sleeve or article.

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      The thermoplastic mid-layer is preferably electrically insulating and/or preferably substantially rigid, by which is meant at least sufficiently rigid to retain the inner layer in a radially expanded state prior to recovery. When used with the preferred elastomeric inner layer, softening of the mid-layer by the application of heat may permit the elastomeric recovery force of the expanded inner layer to shrink the sleeve or article. It will often be preferred that the mid-layer itself be heat-shrinkable to cause or contribute to the dimensional

recovery of the sleeve or article. The mid-layer accordingly may be made from heat-shrinkable thermoplastic materials known per se, for example semi-crystalline polyolefins or olefin co-polymers, which are well known and require no further explanation for those familiar with heat-shrink polymer technology. The usual cross-linking agents and other 5 additives, for example colourings, fillers, antioxidants, may optionally be included in the usual quantities as known per se in all three layers.

The conductive outer layer of the sleeve or article is preferably formed of polymeric material, for example the thermoplastics mentioned above, containing appropriate amounts of 10 electrically conductive carbon blacks and/or other suitable electrically conductive fillers, as known per se.

Examples of suitable compositions for the three layers of articles according to the present invention include the following, using known materials of the kinds indicated in 15 proportions by weight selected within the specified ranges to total 100%:

Conductive Outer Layer

60-70%wt EVA (Ethylene/Vinyl Acetate copolymer)

10-20%wt HDPE (High Density Polyethylene)

15-25%wt Conductive carbon black

20 1-2%wt Aromatic amine antioxidant

Insulating Thermoplastic Mid-Layer

60-70%wt LLDPE (Linear Low Density Polyethylene)

30-40%wt Filler

25 1-2%wt Stabiliser

Insulating Elastomeric Inner Layer

40-50%wt EPDM (Ethylene Propylene Diene Monomer rubber)

10-20%wt PIB (Polyisobutylene)

30 25-40%wt Filler

2-5%wt Process aids

3-7%wt Stabilisers

3-5%wt Crosslinking agent

5 The three-layered sleeve or article of the jointing according to this invention is preferably of tubular, one-piece construction. The term "tubular" is used to indicate an elongate hollow article, which may be a substantially straight sleeve of substantially uniform round or oval cross-section, but is not necessarily limited to any particular longitudinal outline or uniformity of transverse dimensions.

10 The sleeve or article, especially sleeves of regular cross-sectional shape, may be manufactured efficiently by extrusion. However, layered mouldings are not excluded and will often be preferable for articles of more complex shape.

15 As the thermoplastic mid-layer is substantially rigid prior to its recovery and therefore during storage conditions, the thickness of the conductive outer layer can be made thinner as compared to the previously known product. This is because the conductive outer layer now only has to perform an electrical function and is no longer required also to provide the hold-out mechanism, which is separately provided by the mid-layer. In addition, because the mid-layer need not carry the high loading of electrically conductive filler required in the outer layer, adequate hold-out performance can be achieved with a relatively thin mid-layer. Furthermore, an insulating mid-layer may be used to contribute to the total insulation 20 thickness, thus allowing reduction of the inner insulation layer thickness. With the preferred elastomeric inner insulation, reduction in thickness reduces the elastomeric recovery force which the hold-out mid-layer must bear during storage, enabling further reduction in the hold-out thickness. Some or all of these reductions may accordingly be used to provide a sleeve or 25 article whose total wall thickness is significantly less than that of the previously known jointings, thus usefully reducing bulk and weight, and importantly allowing heat to penetrate more quickly and bring about faster recovery, which is a considerable advantage in commercial use of the jointing according to the present invention.

30 The present invention will now be described by way of example with reference to the accompanying drawings, in which

Figs. 1a and 1b are respectively transverse sectional views of the pieces of a first, conventional two-piece heat-shrink jointing as described above;

Fig. 2 is a transverse sectional view of a second conventional, one-piece heat-shrink jointing as also described above; and

Fig. 3 is a transverse sectional view of a heat-shrink jointing in accordance with the present invention.

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A heat-shrink jointing as shown in Fig. 3 comprises a sleeve 10 in the form of a one-piece, tubular extrusion which is made up of three co-axial radial layers, 11, 12 and 13. The innermost layer 11 comprises an electrically insulating layer comprised of an elastomeric material. The outermost layer 13 is thin and made of conducting material. Between the inner 10 and outer layers 11 and 13 is a rigid, thermoplastic mid-layer 12. The mid-layer 12 is recovered by the application of heat thereto and therefore prior to installation of the jointing 10 acts as a hold-out to retain the elastomeric inner layer 11 in a radially expanded state. In addition, the mid-layer 12 is preferably comprised of an electrically insulating material which provides the advantage that the elastomeric, insulating inner layer 11 can be made thinner 15 than would otherwise be the case.

As aforementioned, because the thermoplastic mid-layer 12 is rigid prior to its recovery and therefore during storage conditions, the thickness of the conductive outer layer can be made thinner, for example 0.5mm as compared to 4mm in the prior art described 20 above. The mid-layer may provide adequate hold-out performance at a thickness of only 5mm, allowing a reduction in the elastomeric inner layer thickness, for example from the previously known 11mm to only 6mm, thus maintaining a total 11mm insulation thickness. The resulting wall thickness of all three layers combined may thus be only 11.5mm, which is significantly less than the total 15mm thickness of the previously known sleeves having the 25 dual-function conductive-and-hold-out layer.

A further advantage arises from the fact that as the insulation layer of the jointing 10 is made up of the inner layer 11 and mid-layer 12, the mid-layer 12 does not need to be thick-walled as in the prior art described above with reference to Fig. 1b. This means that a single 30 tubular sleeve can be used as a jointing even for power cables operating at higher voltages without multiple sleeves being required.

Also, as the thermoplastic mid-layer 12 has a faster installation speed than the elastomeric insulation material, the replacement of some of the elastomeric material by an

insulating thermoplastic material in the mid-layer 12 of the present invention improves the recovery speed of the jointing as compared with the prior art.

It will thus be appreciated that the jointing of the invention comprises a hybrid jointing 5 that combines both thermoplastic and elastomeric layers to alleviate the weaknesses of purely elastomeric jointing sleeves and of those elastomeric jointings which only comprise two layers.

In view of the foregoing advantages, it is estimated that there will be potential 10 installation speed improvements of around 30%, perhaps as much as 50%, compared to the elastomeric insulating jointing 5 described with reference to Fig. 2. Also, a single-sleeve jointing 10 in accordance with the present invention should be sufficient for electrical power cables operating at voltages between 12 kV and 42 kV inclusive as compared to the multiple sleeve arrangements required with heat-shrink-only jointings 1, 2 as described with reference 15 to the Figures 1a and 1b.